JPRS: 3669

10 August 1960

ELECTRONICS AND CYBERNETICS

- USSR -

by A. I. Berg

Distributed by:

OFFICE OF TECHNICAL SERVICES
U. S. DEPARTMENT OF COMMERCE
WASHINGTON 25, D. C.
Price: $0.50

U. S. JOINT PUBLICATIONS RESEARCH SERVICE
205 EAST 42nd STREET, SUITE 300
NEW YORK 17, N. Y.

F O R E W A R D

This publication was prepared under contract by the UNITED STATES JOINT PUBLICATIONS RE-SEARCH SERVICE, a federal government organization established to service the translation and research needs of the various government departments.

JPRS: 3669

CSO: 4160-D

ELECTRONICS AND CYBERNETICS

/Following is a translation of an article by A. I. Berg in the Russian-language periodical Izvestiya Vysshykh Uchebnykh Zavedeniy-Radiotekhnika (News of Institutions of Higher Education -- Radio Engineering), Kiev, Vol. III, No. 1, 1960, pages 3-12./

(A stenographic abridgement of a lecture given at the Faculty of Automation and Computer Engineering, Moscow Order of Lenin Power Engineering Institute, September 1959)

INTRODUCTION

Cybernetics is a most interesting field of knowledge and all of us, specialists in electronics, automation and power engineering, must devote ourselves to its development. It is our duty to place all the achievements of science at the service of the Soviet people and apply these achievements to the building of communism in the Soviet Union. Cybernetics can contribute to this end and must be regarded from this point of view.

Increased labor productivity is at the foundation of any progress. Man broke away from the animal world when he began to use the simplest, primitive tools of production. All subsequent progress has been associated with the increase in labor productivity which man achieved by use of the simplest instruments, machines and mechanical systems. It developed that man advantageously combined his efforts with those of other people in order to meet their common needs, that human society was better able to cope with natural obstacles when it became organized.

As man becomes liberated from domination by the forces of nature and the use of machines and engines for production increases and, also, as life and the interaction of individual members or groups of human society become more complex, the problem of control becomes increasingly important. Purposeful control of production processes and human activity is now just as difficult a problem as the creation of the most precise machines and engines. In our time organizational problems, particularly problems of control, have become extremely important. The rate of progress depends just as much on the successful solution of these problems as on the most advanced technical facilities.

The problems of control of production processes are being solved by automation and mechanization.

In the last few decades there occurred a rapid growth in industry, transportation and communication. The needs of the people of the world continued to rise. Small and large wars occurred, and then came the dreadful Second World War. The world was divided into two camps.

In the camp of capitalism the chief stimulus of all the owners of the means of production is gain and profit, gain at any price, by any means, at the expense of the workers and farmers. In the second camp, in the world of socialism, there is posed the problem of how best to meet the needs of the people, the owners of all the means of production in the country.

In time of war as in time of peace, regardless of purpose, every effort is directed toward increasing the effectiveness of man's activity in whatever sphere he may work. This requires not only an in increase in the quality of the means of production but also that man be provided with technical facilities for control.

As has often occurred in history, basic contradictions arise in the conduct of a war. During the last war complex military operations required more advanced methods of controlling the vast, highly-integrated masses of troops. It was here that there arose the necessity for radical changes in the organizational forms and techniques of control.

Subsequently, after World War II, it became possible to devote great attention to man's economic activity. As a result of expansion of the bases of production, the ever-increasing labor force, the intensification of production processes and the necessity of increasing labor productivity there arose the same difficulties in control as had arisen during the 1920's in the organization of military operations. It appeared that here was an impasse for which there was no solution. However, this solution was provided by electronics. It placed as man's disposal completely new technical possibilities for increasing the effectiveness of his activity by the control of complex processes and operations.

The first electronic computer, developed fifteen years ago, immediately opened vast possibilities for execution of the extremely complex mathematical operations which were the foundation of industrial and economic activity. The technical facilities opened the way for improved work organization. Thus was born the science of control known as "cybernetics."

Hence, the emergence of the new science of control in our time is the perfectly logical consequence of the complication of human activity in an age of rapid technical progress. As this science has grown it has become apparent that all control processes and operations have much in common. Control of complex production processes, military operations, economic activity, or of the therapeutic and prophylactic

activities of the medical specialist and biologist are all based on the same principles regardless of the objectives and the tasks to be solved. This also required that the science of control be distinguished as a special discipline designated by a special term.

It is possible either to control the processes occurring in matter or to control the actions of men. Here we refer to physical and chemical phenomena, to human operations or actions. In the first case the reference is to the typical production process in order to obtain a required product with a minimum material outlay. In the second case reference is to the control of human activity, providing men with the machines which facilitate control of large groups of persons engaged in cooperative undertakings. This consists chiefly in the operations of finance, credit, banking, discounting, insurance, trade, military, etc. Regardless of whether control is to be applied to production processes or to operations, any control consists of a series of operations (gathering and processing of data, analysis for the adoption of a solution, formulation and realization of control commands) executed in sequence in order to achieve a given purpose.

In all operations it is necessary to examine the object and subject of control and the possible relationships between them and the purpose of control.

I wish to emphasize that the transfer of an object from one state to another must serve a definite purpose. This purpose should be known beforehand or evolved during operation. In considering the conditions which arise during control, it is necessary to deal with the time factor, since in many cases rates are of decisive importance.

It is also necessary to consider the complexity of the problem to be solved. It is not always that an operation is so complex that its control requires the application of cybernetics. Take the example of operational control of street traffic. The militiaman directs traffic at an intersection, guided by instructions, his observations and sound judgment. Here there is no need for any special skill or complex technique, nor, of course, for cybernetics. This is a most simple, elementary operation; but such simple operations are performed simultaneously by hundreds and thousands of militiamen at intersections in large cities. In most cases these operations are uncoordinated and the militiamen operate independently of one another (excepting those instances in which posts are mutually visible).

This uncoordinated traffic control results in the accumulation of a large number of pedestrians and vehicles waiting for crossing and resumption of movement. There naturally arises the task of achieving orderly traffic within the rayon and the city by gathering information on the flow of street traffic in the various rayons of a city and processing it. Such operations can result in an increase in the rate of vehicular traffic throughout a city, fuel economy and a decrease in traffic accidents.

The investigation of methods of controlling traffic can be extended to adjacent sectors and time segments can be so established that the chosen variant of control of all traffic will be most advantageous.

Finally, there may be posed the problem of automatic control in an optimum variant for a given time of day. In analyzing this example we see that it contains all the features characterizing a complex operation: gathering information, processing and analyzing it, stating the final problem and developing a control variant which may be the optimum among all possible variants.

As interrelated objects are included, the simplest operation becomes a typical cybernetic problem -- the control of a complex operation. Naturally there are no simple means for the solution of such a problem. It can be solved only on the basis of mathematical logic, the theory of probability and mathematical statistics. In order to obtain the results of investigation of the different variants rapidly it is necessary to use electronic calculating devices.

It is well to point out that cybernetics is a completely new and young science. Within it are many undeveloped problems, many controversial points. Among specialists engaged in the field of cybernetics there are divergent views on a number of problems. Even the terminology is extremely confusing and remains to be defined. Thus, in entering upon the study of this science one is studying a science which is in the stage of development.

The people of my generation had to live through such a stage in the development of radio engineering and radio physics many years ago. At that time there were no scientific research institutes, just as there are no cybernetics institutes today. We could not then imagine what would come of radio electronics, what importance it would acquire. Each day brought something of interest. And none of us, now advanced in years, regret that we have devoted our lives to this interesting science. Those who are now engaged in the field of cybernetics are confronted with the same prospect.

As it developed, radio electronics, born many years ago as a means of achieving communication between ships at sea, became a powerful instrument for the propagation of information. There gradually evolved the concept of the amount of information which could be transmitted over a single radio channel; in particular, there evolved the concept of optimum utilization of channels.

It is evident that the amount of information transmitted in color television is infinitely greater than was transmitted in the early days of radio during the transmission of the simplest telegraph signals.

Nowadays, insuring the collection and transmission of information is no longer of uppermost importance in electronics. Electronic computers have led to a definite revolution in computing techniques and now, as cybernetic techniques and automation develop, they open completely new horizons for the application of computer methods in

the field of physical and mental labor. This is of decisive importance in the struggle for technical progress. For us, the representatives of the Soviet people and science, it is important not to forget that it is precisely on the front of labor productivity that there will be solved the problem of when we are to overtake and surpass the capitalist world. Vladimir Il'ich Lenin pointed this out time and again. Hence the task of increasing the effectiveness of control becomes particularly important and begins to acquire political significance.

The purpose and task of cybernetics is the development of more effective methods, means and systems of control of processes and operations. The content of cybernetics is the study of the regularities which lie at the basis of all control.

It is necessary to distinguish theoretical or abstract cybernetics, applied and technical cybernetics.

Theoretical cybernetics is essentially a philosophical and mathematical science. It includes divisions of mathematics: the theory of games and operations, the theory of algorithms, information theory, etc.

Applied cybernetics solves specific practical problems in the control of complex processes and operations in various fields of human activity in industry, economics, biology and medicine.

Technical cybernetics combines the problems associated with the design and manufacture of the technical facilities (control devices and computers, instruments, etc.) required for the solution of problems in applied cybernetics.

INFORMATION THEORY

Information theory, as an independent discipline, deserves particular attention; it virtually penetrates all fields of cybernetics and constitutes its basic content.

Hence, all features of information theory as developed in the field of communications are fully applicable in cybernetics, both for the study of problems and processes of control of production processes and scientific research as well as for the study of the processes and phenomena which occur in the human organism without the participation of human consciousness. In the latter case, of which I shall speak later, there occur along the channels of the nervous system controls which are subject to the same laws of passage of signals as communications channels.

Information theory, which deals with the problems of capacity of communications channels and optimum coding of signals, is of great practical importance.

There are at present a large number of measuring instruments converting primary information into electrical signals. However, these electrical signals are not standardized and this causes considerable difficulty in using them in electronic control devices in achieving the reception, processing and read-out of control information. Much

effort will be required in converting primary instruments and transducers to a unified output in the form of a standard code suitable for transmission along a communication channel and input into control devices.

The information must be transmitted along communications channels. The signal or group of signals containing a definite information are distorted by the communications channels.

Information theory studies the properties of various communications channels for the purpose of transmitting information along them with minimum losses and distortions.

It is of interest to us that the information arrive in good time, that it be precise, without error, authentic and reliable, and noncontradictory. Redundant information contains more data than is necessary, part of the data being contradictory and part of it unnecessary. It simply retards the rate of transmission of information. Communication channels must transmit that information which is necessary to achieve control. Sometimes, due to noise or poor design, communication channels transmit incorrect information.

Fortunately for mankind, the systems and codes which form our language possess redundant information, which permits us to restore meaning to distorted texts. But sometimes distorted information enters devices which are incapable of making semantic distinctions and normal operation ceases.

Machines possess finite memory. High-speed electronic computers operate with memories of some thousands of characters.

Man, on the other hand, possesses a cerebral cortex with approximately 15 billion neurons and he can store in his memory the equivalent of several libraries. The processing of information in an electronic computer requires clear instructions (algorithms) which are transmitted from the control block and determine the course of the computing process. The theory of algorithms is a rapidly expanding branch of mathematics and mathematical logic. The construction of optimum computing and control algorithms is of vast practical importance.

One of the tasks of theoretical cybernetics is the synthesis of systems performing assigned functions with a minimum number of links and elements.

APPLICATION OF CYBERNETICS IN BIOLOGY

Cybernetics embraces the processes occurring in living nature, particularly in living organisms. Here there is a continual process of automatic control based on the interrelation of the physical and chemical processes which determine the nature of the life activity of the organism. The singular aspect of this field is the absence of conscious purpose, of human intervention.

As the result of adaptation of the organism to external conditions over a long period of time, biological processes usually follow

the course most suitable to the organism. Industry, whatever degree of complexity and perfection it achieves, is the result of man's activity and is subordinate to his will. Comparing the phenomena occurring in industry and in the organism, we see that in both cases there occurs control of complex processes consisting in the gathering, storage and transmission of information and the elaboration of control commands.

The difference between these processes lies in the fact that in the control of processes in inanimate nature the solution, in the final analysis, always rests with man, although this may prove, at different levels, to be control of a complex process.

In the control of processes in living organisms human reason and consciousness are often excluded and the process of control occurs automatically. Man is striving to study and understand the principles of control achieved by different organs, nerve cells and centers.

I particularly wish to point out that at the Twenty-First Party Congress Nikita Sergeyevich Khrushchev emphasized that the necessary theoretical premise for advancement of medical and agricultural sciences is the development of the complex of biological sciences. Importance of the complex of biological sciences will increase particularly in proportion to the application of the achievements of physics and chemistry.

There exists the greatest basic difference between that which man can control by means of technical facilities and that which occurs in the human organism. That which occurs in the human organism is so complex that one may doubt the effectiveness of applying the methods of cybernetics to the study of these phenomena.

Our times are characterized by increasing rapprochement between mathematicians and biologists as well as engineers. This could hardly have been foreseen in the years gone by. Simulation is often employed in studying the complex processes of physics and other applied sciences. It develops that the complex biological processes of life activity may also be simulated. Both abroad and in the Soviet Union considerable progress is being achieved in simulating the processes of higher nervous activity.

I wish to mention an extremely important problem associated with diagnostics. It is known that heart diseases now claim more lives than cancer and all the infectious diseases combined. However, serious difficulties are encountered in the diagnosis of this affliction. Different heart diseases have the same symptoms and the same disease may have different manifestations in different people. This complicates and obscures the symptoms of sickness. What is required is vast personal experience on the part of the doctor and skill in studying and comparing numerous symptoms, each of which may be of secondary importance, but, in combination with other symptoms, permits identification of the disease.

High-speed electronic computers show great promise for application in this field.

These computers permit rapid review of numerous variants and comparison of observed symptoms with those symptoms which are stored in the computer memory and relate to the specific disease.

Processing of observations requires application of the methods of mathematical logic and mathematical statistics. However, as a rule, these methods will not be used by doctors.

Accumulated in our hospitals are hundreds of thousands of observations which have not been presented in generalized form. Needless to say, sound and effective processing of the vast accumulation of experimental material is impossible without the development of special methods. These methods are to be found in mathematical statistics.

The problems of biology, in view of their special complexity, have long remained without interest for the mathematician, just as mathematics has held no interest for biologists. But in recent years it has become necessary to create special methods for the quantitative description of characteristic vital processes.

There are two points of view. One considers biological processes so complex that it is impossible to investigate them with cybernetic methods and mathematical statistics. The other considers the processes occurring in certain areas of biology so simple that there is no need for the application of cybernetics. Needless to say, both these attitudes are extreme.

Cybernetics is now making considerable progress in the field of biology. Recently at the Ukrainian Academy of Sciences scientists built a computer for diagnosis of heart disease. Yet we have found that there are sceptics who believe that the use of electronic diagnostic methods nullifies the talent, experience, understanding and intuition of the expert doctor-diagnostician. In the meantime diagnosticians continue to obtain information by extremely primitive means and, on the basis of wholly inadequate information, it is often attempted to prepare an accurate diagnosis. Diagnostic computers will not replace the doctor, but they will assist him in his decisions in difficult cases.

APPLICATION OF CYBERNETICS IN LINGUISTICS

There are now approximately three billion people on earth speaking several thousand languages and not understanding one another. Despite the efforts of numerous scientists and inventors it has not been possible to create an international language, not even for science or international relations. In 1887, a Warsaw linguist, L. Zamenhof, created the international language known as Esperanto. This language, however, has not found wide acceptance.

Now, with the appearance of the computer, there is revealed the possibility of rapid translation from one language to another and the creation of an intermediary language possessing extremely valuable properties.

An analysis of Esperanto by the methods of mathematical statistics showed that this language is not economical. The number of characters which must be used for the transmission of a given amount of information is greater than is necessary, greater than in the English language. Nevertheless, the effort to create an intermediary language deserves encouragement.

At the present time there is in progress a very interesting process of mathematical representation in linguistics. The representation of the structure of language has been introduced and a new discipline, structural linguistics, has already found wide recognition.

This new discipline employs mathematical methods of investigation. It serves as the basis for design of text-scanning devices, stenographic devices and devices for oral control of systems and industrial processes.

I have already stated that language is a social phenomenon; and philology is a social science. But this is in no way a hindrance to the development of an abstract science, structural linguistics, and it does not hinder the use of mathematics, set theory, probability theory, topology, mathematical logic and information theory in philology.

Through the study of natural languages structural linguistics develops abstract codes which permit the preparation of groups of symbols as the input for a translating machine.

Applications of cybernetics in linguistics consist in the development of a general theory for the synthesis of symbolic systems, structural linguistics, defectology (the study of defects in speech development), translation theory from the point of view of the mathematical and structural description of language, speech-controlled file computers, et al.

APPLICATION OF CYBERNETICS IN SOCIOLOGY AND ECONOMICS

The next area of application which I wish to discuss is that of sociology. Here we touch upon economics, philosophy and the natural sciences. Here, again, there is the opinion that these problems are so complex that to attempt to study their nature by mathematical methods, even with the use of electronic machines, is useless.

In human society there are usually large numbers and groups of people simultaneously engaged in studying the regularities underlying human activity, which is an extremely difficult undertaking.

But, nevertheless, there exists the possibility of simulating specific problems. It would be extremely primitive to suppose that social processes may be accurately simulated by using the nervous activity of man as an analog. Social processes are nonlinear processes including elements of chance.

Nevertheless, there are numerous facts at hand to attest that the use of modern mathematical methods and high-speed computers in the social sciences holds great promise.

In the field of economics it is time to convert from primitive statistics to the higher forms of mathematical statistics.

Among the more important problems to be studied are pricing, circulation of currency, establishment of norms, etc.

It is well known that under the conditions of a socialist society current and prospective planning of the national economy play an important role. However, thorough processing of refined data, determination of investment rates, expenses, labor estimates, determination of the optimum variant of a plan -- all require extensive calculations. But sometimes the accuracy of calculations is inversely proportional to their timeliness. The use of electronic computers permits elimination or negation of the time factor.

I would like to say a few words about electronic data-retrieval machines. Large data-retrieval machines with memories containing billions of characters have been created. The long-term memories of these machines may be compared with the information stored in a library, but they are usually specialized and particularly valued for their high access rates. Development of such data-retrieval machines has been the subject of great attention in recent years.

Extensive use of computers is having considerable effect on sociology. The vast number of factors relating to social existence which are reduced to general principles by these machines will undoubtedly stimulate theoretical investigations as well.

Application of the achievements of cybernetics in the social sciences is disclosing wide possibilities.

Let it be pointed out that it is precisely under the conditions of a socialist society that application of cybernetics to the study of the social sciences is most desirable, for here there occurs a deliberate guidance of planned national economy and the activity of the people of our society.

In distinction from capitalism, in socialism there are no classes which can be intent on distortion of scientific facts (including distortions achieved by means of cybernetics) nor on distortion of the laws of development of science. There are no such classes to hinder the practical application of the achievements of science.

It must be stated that there is hardly any other branch of science which is so needful of the application of cybernetics as economy. It is known that we have hundreds of thousands of industrial units in which numerous machines of the most complex type are in operation. They must operate in harmony, according to a single, definite coordinated plan. Mutual relationships must be planned between branches and enterprises, both within the limits of the Sovnarkhoz and within each republic and the entire country.

There are now many sociologists, economists and mathematicians who are engaged in creative work in this field, but, regrettably, there are also those conservatives who were mentioned at the June Plenum of the TsK KPSS /Central Committee of the Communist Party of the Soviet Union/.

APPLICATION OF CYBERNETICS IN INDUSTRY

At the basis of those facilities which are used by modern cybernetics are electronic instruments, apparatus and machines. Hence, I have devoted my lecture to electronics and cybernetics. Without electronics cybernetics could not have been developed. Electronics is the means on which cybernetics is based.

Practical considerations require that we use electronic control devices in increasing labor productivity and the effectiveness of human activity (particularly in production), in controlling industrial processes and in conducting these processes under optimum conditions.

The importance of automation and mechanization of industrial processes was emphasized in the decisions of the June Plenum of the TsK KPSS.

The difficulties encountered along this path are extremely varied.

In the execution of this task, as in any matter, the decisive role belongs to man -- conscientious, well-trained, honest and competent.

It is obvious that an ill-informed person can create nothing competent in the field of organization; yet organizational problems are foremost among the problems to be solved. The principal organizational problem is that of methods of control for the creation of optimum conditions for the execution of industrial processes.

Naturally, it is not advisable to introduce automation into an outmoded technology, to control obsolete machine tools and equipment. Of course, we may apply automatic electric drive and an electronic device to a machine built in 1885 and consider that this will give an increase in the output of the machine. But there is no need for this kind of automation.

The value of electronic automation lies in the fact that it permits a radical change in technology, and labor productivity will increase in proportion to this change.

Automation in itself, linked to the old technology, cannot provide the required result. It is extremely regrettable that this is not always understood.

But even electronics has its "Achilles heel." As is known, the reliability of a complex system depends on the reliability of individual elements. There are precise objective methods for the analysis of complex processes and systems, but they all lead to the conclusion that the greater the interdependence of individual elements, the less reliable the system.

The operational reliability of electronic equipment is now a most important problem, for we cannot expect to control production with unreliable facilities.

It is necessary that we have at our command scientifically based methods of gathering, analyzing and systematizing information concerning the operational reliability of the various systems. This is a most

important problem for science and the government, but it is inadequately understood and we do not have at our command (nor is there as yet available anywhere in the world) precise objective information concerning the reliability or unreliability of the instruments and systems which we have at our disposal.

The theoretical analysis of reliability is of great significance. In this connection the reliability of instruments and apparatus depends on the efficiency of the technological process of their manufacture.

CONCLUSION

In this brief report I could touch only on a few aspects of cybernetics as it is developing on the basis of mathematics, automatics and electronics. It was my objective to command the interest of the audience and to show what great tasks have been revealed by cybernetics.

There exists the likelihood of underestimation of the possibilities of cybernetics under our Soviet conditions, but it is precisely under these conditions that the entire activity of the Party and the Government is directed toward meeting the needs of the people and, under these conditions, there is opened before us the possibility of organizing the most effective forms of control. Correct organization of control may sometimes provide results considerably exceeding those which may be provided by automation. Hence work on the ideological front must be directed not only to criticism of bourgeois idealistic errors in the field of cybernetics but also to comprehension of the modern achievements of science and engineering and, chiefly, to creative research for the most rational use of these achievements under our conditions.

In conclusion, I wish particularly to point out that at the June Plenum of the Central Committee of our party on 29 June 1959 reference was made to conservatism, and cybernetics is not compatible with conservatism. The Plenum of the Central Committee considers that defects are engendered by technical conservatism, by habitual attraction to the old, to old methods of production and instruments of labor and to the reluctance of many industrial managers to overcome the difficulties associated with the introduction of new techniques.

For this reason the Decisions of the Central Committee state that the greatest task of the Academy of Sciences USSR, the Academy of Construction and Architecture USSR, the academies of sciences of the union republics, the branch scientific research institutes, and of all Soviet scientists is the utmost creative development of science and engineering into an indissoluble bond with the practices of socialist construction. Cybernetics must be used in fulfilling this task, it must assist in solving the problems of increasing the productivity of the mental and physical labors of man. There must be created in our country a school of Soviet cybernetics unhindered by the errors of bourgeois science.

Recommended by the Chair of Automation and Telemechanics, Moscow Order of Lenin Power Engineering Institute

Submitted to Editor 22 October 1959

5301

- END -